Measurement of π^0, η and K_s^0 mesons with TeV energies by using LHCf detectors

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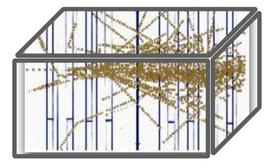
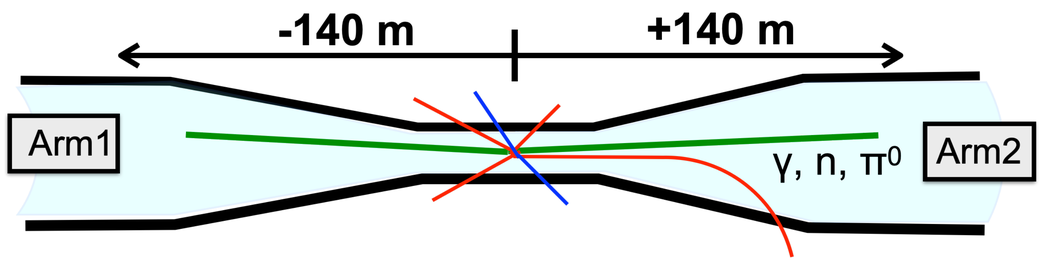


Introduction

The LHC forward (LHCf) experiment measures energetic neutral parrticles such as π^0 emitted in the very forward region of pp collisions at LHC. The aim is to provide essencial calibration points of hadrnic interaction models which is used for simulations of air showers caused by interactions of very high energy cosmic rays with atmospheric nuclei.

The LHCf has two independent detectors (Arm1 and Arm2) that had been installed +/- 140m from the ATLAS interaction point. Each detector has two sampling and imaging calorimeter towers. The detectors are installed into the narrow gaps between the LHC beam pipes connecting to the beam separation chambers and view zero degree of LHC collisions. The detectors are able to measure only neutral particles because charged particles are swept away by magnetic field of the dipole magnets located between IP and the detectors.



Operation

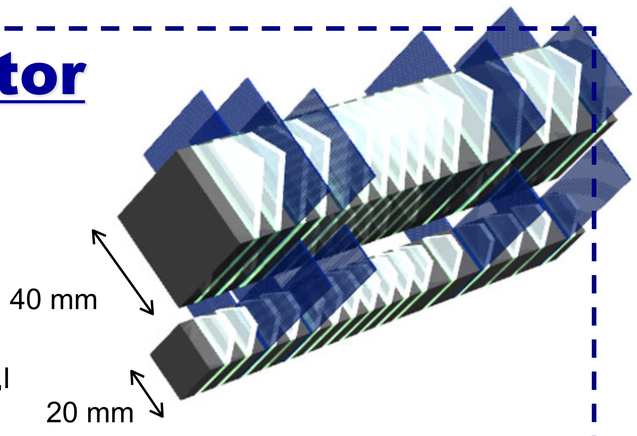
- pp at $\sqrt{s}$ = 0.9, 2.7, 7, 13, 13.6 TeV
- p-Pb at $\sqrt{s_{NN}}$ = 10 TeV
- p-Oxgen in **"2025"**

Operation Condition

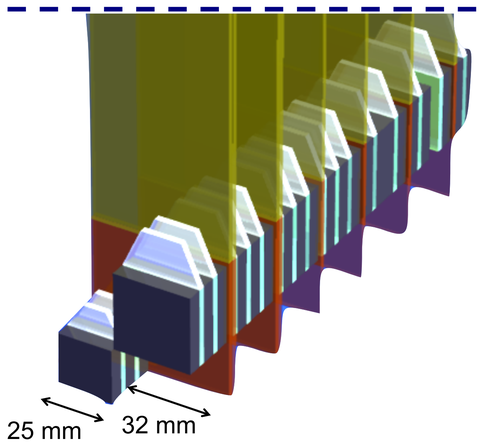
- Pseudo rapidity coverage η > 8.4
- Luminosity L ~ 10^{28} – 10^{30} cm^2s^{-1}
- Joint operation with ATLAS

LHCf Arm1 Detector

Size : 620mmH x 91mmW x 280mmT
Transverse size of calorimeters:
20x20mm and 40x40mm
Calorimeters:
Tungsten (total length 44 r.l. and 1.7 λi)
16 GSO scintillator layers
Position sensitive layer:
4 GSO bar XY hodoscopes at 6,10,32,42 r,l
Energy resolution : <5% for photons

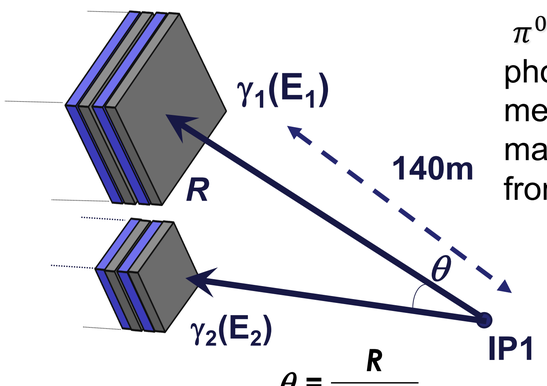


LHCf Arm2 Detector



Size : 620mmH x 91mmW x 280mmT
Transverse size of calorimeters:
25x25mm and 32x32mm
Calorimeters:
Tungsten (total length 44 r.l. and 1.7 λi)
16 GSO scintillator layers
Position sensitive layer:
silicon strip layers at 6, 12, 18, 24, 32, 40 r,l
first 2 layer: x-y pairs, the others: x or y

π^0, η measurement



$$\theta = \frac{R}{140\,\mathrm{m}}$$

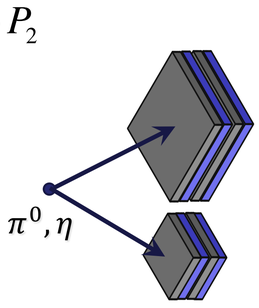
Reconstruction method

π^0 and η immediately decay to two photons at IP. These photon pairs are measured by the LHCf detectors, and its mass and kinematics can be reconstructed from photon energies and hit positions as

$$M_{\pi^0} = \sqrt{E_1 E_2 \theta^2},$$
$$E_{\pi^0} = E_1 + E_2,$$
$$P_{\pi^0} = P_1 + P_2$$

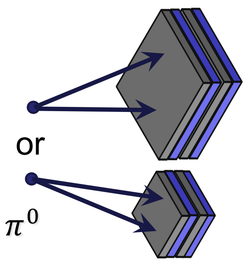
Event Categoly: Type 1

- Events with one photon hit in each tower.
- Sensitive for η and low energy π^0 (E_π < 2 TeV)
- Each photon energy can be simply measured by each calorimeter tower, but an correction of contamination of leaked shower particles between towers must be applied.



Event Categoly: Type 2

- Events with photon pairs in one tower.
- Sensitive only for high energy π^0 (E_π > 2 TeV)
- Only the total photon energy (E_1+E_2) can be measured calorimetorically.
- Energy sharing factor (E_1/ E_2) is estimated using a ratio of peak hight on the lateral distributions measured by the position sensitive layers.

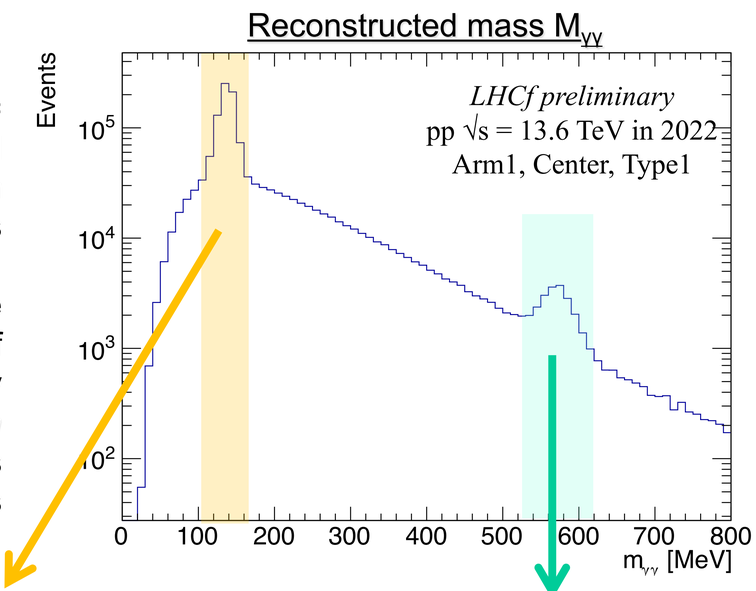


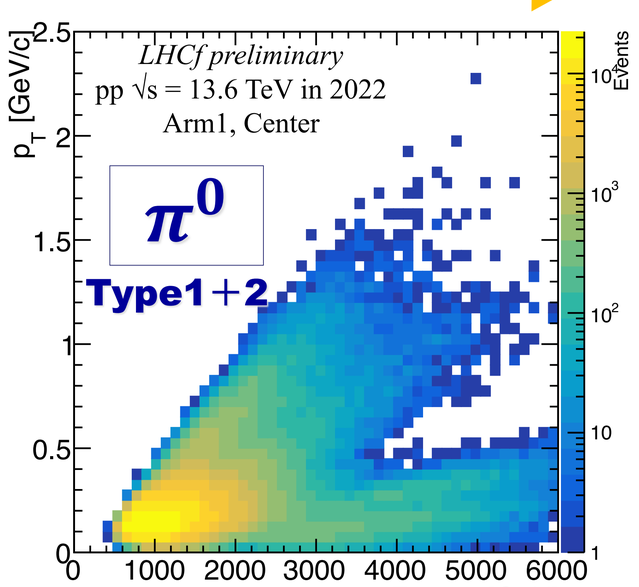
Data in 2022

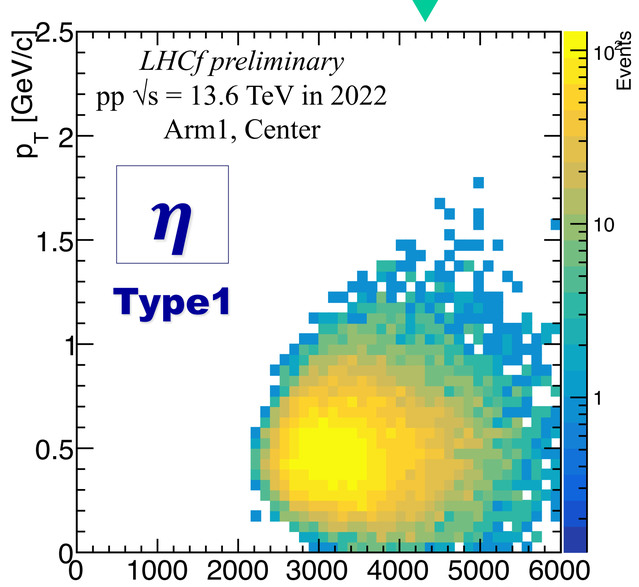
An operation with pp collisions at $\sqrt{s}$ = 13.6 TeV was successfully performed in Sept. 2022, and 300 M events in total have been obtained in this 4-days operation.

The two peak structures on the reconstructed mass distribution of type-1 events (right figure) are clearly found, which correspond to $\pi^0$and η mass. The $\pi^0$and η candidate events have wide phase space coverages including several TeV energies.

Reconstructed mass $M_{\gamma\gamma}$

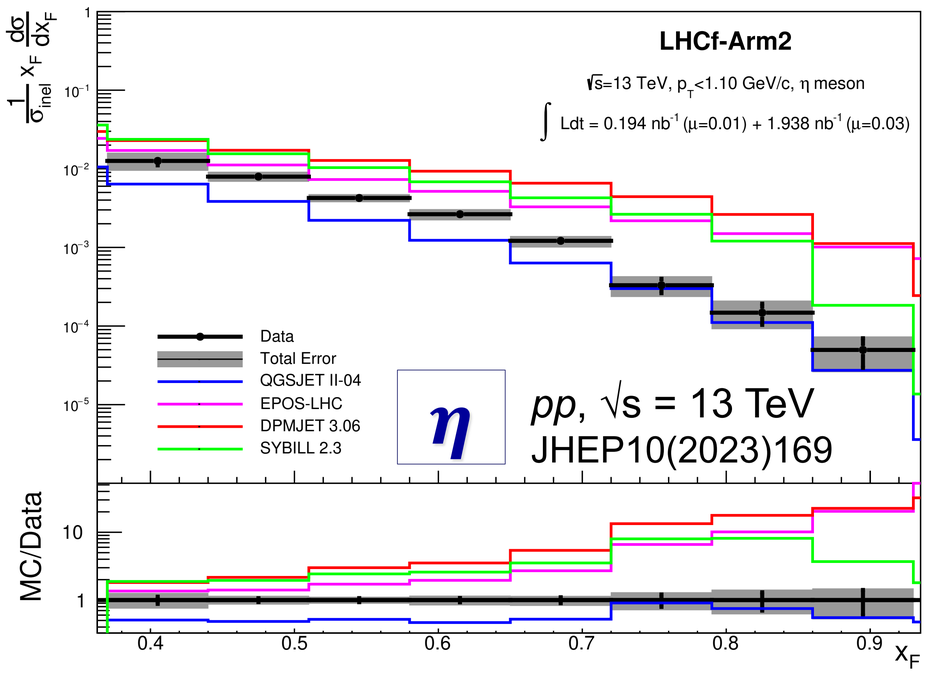




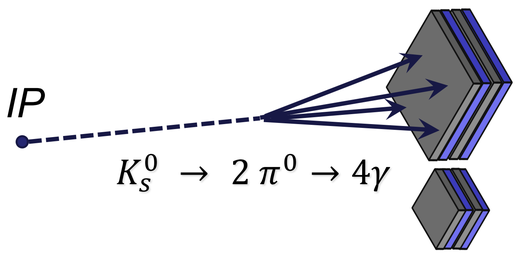


Result from data in 2015

While analyses of data in 2022 are still on-going, many results from data obtained in the past operations, ex. in 2015 with pp at $\sqrt{s}$ = 13 TeV, have been already published. The bottom figure shows the production differencial cross-section of η mesons measured at pp, $\sqrt{s}$ = 13 TeV.

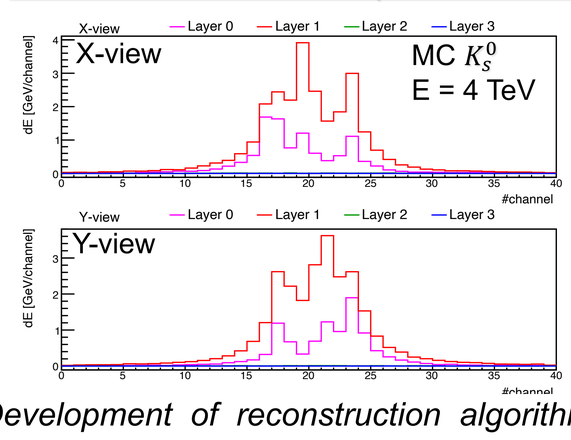


K_s^0 measurement



- K_s^0 decays to 4 γ during flying to the detector
- The decay vertex position can be estimated assuming as $M_{\gamma\gamma} = M_{\pi 0}$.
- The key is to reconstruct energies of individual photon properly.

Lateral distribution of a 4 photon events



Development of reconstruction algorithm is on-going using a machine learning technique

Summary and Prospects

LHCf measures π^0, η and K_s^0 mesons with TeV energies emitted in the forward region of LHC collisions. The kinematic of these mesons can be reconstructed from precise measurements of two or four photons. In addition to the published results, we will provide many results from the data including from a future operaion with p-O collisions scheduled in 2025.